SIMULATION OF MICRO HYDRO POWER BASED ON RIVER CONFIGURATION AT RIVER DOWNSTREAM

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ABSTRACT

Micro hydro power convert potential energy of water into electricity and it a clean source. The project present about Simulation of Micro Hydro Power based on river configuration at river downstream. The objectives of this project to simulate flow of downstream river for different Micro hydro power, to determine the performance and efficiency of micro hydro power in downstream river and to determine the availability of hydroelectric in rural areas. This project is focused on downstream river where the velocity, pressure and topology data is to be determined. The place that used for this project is Sungai Pahang. In this project just used two software, it is SolidWorks 2012 and ANSYS (CFX). Simulations have been done with two different turbine of micro hydro power, the first turbine is Propeller and the second is Tidal turbine. Between the two turbines the performance of Propeller turbine are good compared to the tidal turbine. It is because the toque of Propeller is higher compared to the tidal. The torque is 17.295Nm and 11.901Nm. As the conclusion propeller turbine are beater compare to the tidal turbine.

ABSTRAK

Kuasa mikro hidro mengubah tenaga keupayaan air kepada elektrik dan ia merupakan sumber yang bersih. Projek ini adalah mengenai simualsi kuasa mikro hidro berdasarkan konfigurasi di hilir sungai. Projek ini bertujuan untuk mensimulasikan aliran sungai hilir dengan perbezaan mikro hidro, ia juga bertujuan untuk menentukn kecekapan dan prestasi kuasa mikro hidro di hilir sungai dan ia juga bertujuan untuk kesesuaian diguankan di kawasan luarbandar. Projek ini dikhususkan dihilir sungai dimana kelajuan, tekanan perlu ditentukan. Tempat yang digunakan untuk projek ini ialah Sungai Pahang. Projek ini mengunakan dua jenis perisisan iaitu SolidWorks 2012 dan ANSYS (CFX). Simulasi ini telah dilakukan kepada dua jenis turbin yang berbeza. turbin pertama adalah Propeller dan kedua adalah Tidal.berdasarkan kedua-dua jenis turbin, turbine Propeller lebih baik berbanding turbin Tidal. Ini kerana daya kilas untuk turbin propeller lebih tinggi jika dibandingkan dengan turbin tidal. Daya kilas itu ialah 17.295 Nm dan 11.901 Nm. Kesimpulannya, turbin Propeller adalah lebih baik dibandingkan dengan turbin Tidal.

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psi	pound per square inch
gpm	gallons per minute
m^3/s	cubic meters per second
lpm	liters per minute
l/s	liters per second
m/s	meter per second
kW	kilo watts
P	power
ω	angular velocity
τ	torque
A	swapped area
ρ	density
ν	velocity
η	efficiency

LIST OF ABBREVATION

MHP	Micro Hydro Power
JPS	Jabatan Pengairan dan Saliran
AC	Alternating Current
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays there are many sources that use to sustainable the energy for example micro hydropower, solar energy, biomass, geothermal and etc. The energy is generating from natural resources such as water, radiation, wind and tides etc. which are renewable in nature. Hydro power plants convert potential energy of water into electricity and it is a clean source. The water, after generating electrical power is available for irrigation and purposes. A micro hydro power plant has a capacity of up to 100kW. Micro hydroelectric power system can produce enough electricity for home, farm, ranch or village. Hydroelectric power generated from water is not yet all tapped completely. Micro hydro power plants are emerging as a major renewable energy resource today. However, they require control system to limit the huge variation in input flow expected in rivulets over which these are established so as to produce a constant power supply. This also helps in achieving the competitive cost of generated power which is possible by using hydro power. In planning of micro hydro power plant, it is necessary to mention the power demand of that region. New micro Grid (MG) is to be introducing in existing power system based on the local power supply conditions. Potential improve the Self-supply Ratio (a percentage of the valid power obtained from local power source) in power consumption. It should be considered that in the view of overall condition of energy development, the potential power existing in the weak natural energy regions usually ignored due to low benefit and long repayment period. In reality, almost all parts of region in which people are living are usually with the natural energy. World energy shortage points out that it becomes urgency to develop the weak natural energy around local inhabitants. In economic analysis, it is found that the payback is severely affected by the effective water- head that the water flow rate. It could be observed that to select an irrigation canal with higher water head for installing mini hydro power plant, it is more important than to select a canal with larger water flow rate.

In this project, the simulations have done for micro hydro power at Sungai Pahang. From this experiment the water flow into the turbine and then will rotate the turbine, after that it will generate hydro power. After generation of power, it can use for people that live at the area which is the people that live near to Jambatan Pekan. This concept is useful to utilize untapped renewable energy. Various basic parameters such as section of site, hydrological and topographical survey and its analysis is studied for deciding the suitable micro hydro power.

1.2 PROBLEM STATEMENTS

Geographical factor play an important role in micro hydro power plant. The height (head) of river, velocity of flow, water traffics, river contamination and topology data differs in every place. These factors may affect the performance and efficiency of micro hydro power. Different types of micro hydro power differ in performance and efficiency. The effectiveness of micro hydro power is influenced by surrounding factors.

1.3 OBJECTIVES

The main objective of this project is to simulate flow of downstream river for different turbine in micro hydro power. There are two types of turbine which is Propeller and tidal turbine.

Next objective is to determine the performance and efficiency of micro hydro power in the downstream river configuration.

And the last objective is to determine the availability of micro hydro power in the rural area.

1.4 SCOPES

The analysis that used in this project is for Sungai Pahang. This project focuses on the downstream river configuration where the velocity, pressure and topology data is to be determined.

This project is more focus on simulation of the micro hydro power. All parts in the water turbine system have been done using SolidWorks 2012. Based on the data collected, the simulations have been done using ANSYS (CFX). From the result obtained, we can know the suitable micro hydro power based on higher performance.

CHAPTER 2

LITRTURE RIVIEW

2.1 INTRODUCTION

Following and falling water have potential energy. Hydro power comes from converting energy in following water by means of water wheel or through a turbine into useful mechanical power. This power is converted into electric using an electric generator or is used directly to run milling machines.(DOE, 2001). Micro-hydro power is the small-shale harnessing of energy from falling water; for example harnessing enough water from a local river to power a small factory or village. This fact sheet will concentrate mainly at micro-hydro power.

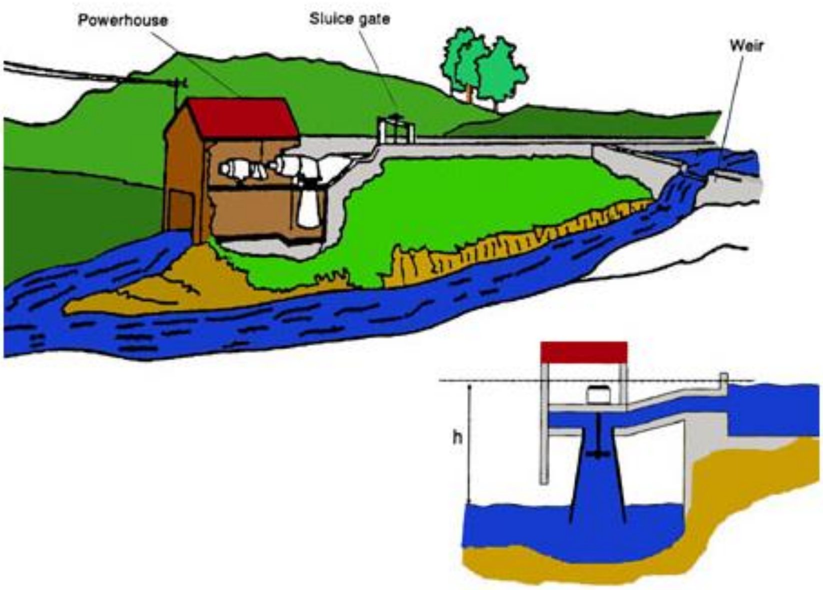

Figure 2.1: A low-head micro-hydro installation

Source: Fraenkel et al(1991)

Table 2.1: Classification of hydropower by size

Type of Hydro Power	Power generated
Large hydro	More than 100MW and usually feeding into a large electricity grid
Medium hydro	15 – 100MW usually feeding a grid
Small hydro	1 – 15MW usually feeding into a grid
Mini hydro	Above 100kW, but below 1MW; either stand-alone schemes or more often feeding into the grid
Micro hydro	From 5kW up to 100kW; usually provided power for a small community or rural industry in remote areas away from the grid
Pico hydro	From a few hundred watts up to 5kW

Source: S.P Adhau, R.M Moharil, P.G Adhau, (2012)

Hydro power plants also classified based on water- head as under:

Table 2.2: Classification of water head

Head	Type
Ultra low head	Below 3 m
Low head	Less than 40 m
Medium/high head	Above 40 m

Source: S.P Adhau, R.M Moharil, P.G Adhau (2012)

To determine the suitable of turbine for micro hydro power, the first thing to known is the head of river. Because from the head of river can determine the turbine using the turbine application chart.

2.2 General Principle of MHP

Power generation from water depends upon a combination of head and flow. Both must be available to produce electricity. Water is diverted from a stream into a pipeline, where it is directed downhill and through the turbine (flow). The vertical drop (head) creates pressure at the bottom end of the pipeline. The pressurized water emerging from the end of the pipe creates the force that drives the turbine. The turbine in turn drives the generator where electrical power is produced. More flow or more head produces more electricity. Electrical power output will always be slightly less than water power input due to turbine and system inefficiencies.

Water pressure or Head is created by the difference in elevation between the water intake and the turbine. Head can be expressed as vertical distance (feet or meters), or as pressure, such as pounds per square inch (psi). Net head is the pressure available at the turbine when water is flowing, which will always be less than the pressure when the water flow is turned off (static head), due to the friction between the water and the pipe. Pipeline diameter also has an effect on net head.

Flow is quantity of water available, and is expressed as 'volume per unit of time', such as gallons per minute (gpm), cubic metres per second (m^3/s), or liters per minute (lpm). Design flow is the maximum flow for which the hydro system is designed. It will likely be less than the maximum flow of the stream (especially during the rainy season), more than the minimum flow, and a compromise between potential electrical output and system cost (Singh.D, 2009)

2.3 Power from a MHP

To know the power potential of water in a stream it is necessary to know the flow quantity of water available from the stream (for power generation) and the available head.

The quantity of water available for power generation is the amount of water (in m^3or litres) which can be diverted through an intake into the pipeline (penstock) in a certain amount of time. This is normally expressed in cubic meters per second (m^3/s) or in litres per second (l/s).

Head is the vertical difference in level (in meters) through which the water falls down.

The theoretical power (P) available from a given head of water is in exact proportion to the head and the quantity of water available.

$$P = Q \times H \times e \times 9.81 \text{ Kilowatts (kW)} \qquad (1)$$

Where,

P =Power at the generator terminal, in kilowatts (kW)

H =The gross head from the pipeline intake to the tail water in metres (m)

Q =Flow in pipeline, in cubic metres per second (m^3/s)

e =The efficiency of the plant, considering head loss in the pipeline and the efficiency of the turbine and generator, expressed by a decimal (e.g. 85% efficiency= 0.85) 9.81 is a constant and is the product of the density of water and the acceleration due to gravity (g) (Singh D, 2009)

This available power will be converted by the hydro turbine in mechanical power.

2.3.1 The losses in a hydro plant are

Losses in energy caused by flow disturbances at the intake to the pipeline, friction in the pipeline, and further flow disturbances at valves and bends; and loss of power caused by friction and design inefficiencies in the turbine and generator.

The energy losses in the pipeline and at valves and bends are called head losses: they represent the difference between the gross head and the net head that is available at the turbine. The head losses in the pipeline could range from 2 percent to 10 percent of the gross head, depending on the length of the pipeline and the velocity of the flow. The maximum turbine efficiency could range from 80 percent to 95 percent depending on the type of turbine, and the generator efficiency will be about 90 percent.

Usually for design purposes, the head losses can be combined with the losses in the turbine and generator, and an overall plant efficiency of 85 percent (or e = 0.85) can be used. (Singh. D, 2009)

2.4 Component of MHP

2.4.1 Turbine

Turbine is the main piece of equipment in the MHP scheme that converts energy of the falling water into the rotating shaft power. The selection of the most suitable turbine for any particular hydro site depends mainly on two of the site characteristics – head and flow available. All turbines have a power-speed characteristic. This means they will operate most efficiently at a particular speed, head and flow combination. Thus the desired running speed of the generator or the devices being connected/ loading on to the turbine also influence selection. Other important consideration is whether the turbine is expected to generate power at part-flow conditions.

The design speed of a turbine is largely determined by the head under which it operates. Turbines can be classified as high head, medium head or low head machines. They are also typified by the operating principle and can be either impulse or reaction turbines. The basic turbine classification is given in the table below:

Table 2.3: Turbine application

Turbine	**Head (Pressure)**		
	High (30m +)	**Medium**	**Low (<10m)**
Impulse	Pelton Turgo	Cross flow Pelton Turgo	Cross flow
Reaction	-	Francis Pump	Propeller Darius

Source: Singh, D. 2009

Impulse Turbine, which has the least complex design, is most commonly used for high-head micro hydro systems. They rely on the velocity of water to move the turbine wheel, which is called the runner. The most common types of impulse turbines include the Pelton wheel and the Turgo wheel.

Difference between impulse and reaction turbines

The rotating part (called ‘runner’) of a reaction turbine is completely submerged in water and is enclosed in a pressure casing. The runner blades are designed in a manner such that the pressure difference across their surface imposes lift forces (similar to the principle used for airplane wings) which cause the runner to turn/rotate.

The impulse turbine (as the name suggests) on the other hand is never immersed in water but operates in air, driven by a jet (or jets) of water striking its blades. The nozzle of the penstock converts the head of the water (from forebear tank) into a high speed jet that hits the turbine runner blades that deflect the jet so as to utilize the change of momentum of the water and converting this as the force on the blades – enabling it to rotate.

Impulse turbines are usually cheaper than reaction turbines because there is no need for a pressure casing nor for carefully engineered clearances, but they are also only suitable for relatively higher heads.

1. Pelton turbine

Pelton wheel used the concept of jet force to create energy. Water is funnelled into a pressurized pipeline with a narrow nozzle at one end. The water spray out of the nozzle in a jet, striking the double-cupped buckets attached to the wheel. The impact of the jet spray on the curved buckets creates a force that rotates the wheel at high efficiency rate of 70-90%. Pelton wheel turbines are available in various sizes and operate best under low-flow and high-head condition.

Figure 2.2: Pelton Turbine

2. Turgo turbine

Turgo impulse wheels an upgraded version of the Pelton. It uses the same jet spray concept, but the Turgo jet, which is half the size of the Pelton, is angled so that the spray hits three buckets at once. As a result, the Turgo wheel moves twice as fast. It's also less bulky, needs few or no gears, and has a good reputation for trouble-free operations. The Turgo can operate under low-flow conditions but requires a medium or high head.

Figure 2.3: Turgo Turbine

3. Cross flow turbine

Cross flow turbine is widely considered by many to be the most efficient and apt type of turbine for application in micro hydro projects. Also called a Michell-Banki turbine a cross flow turbine has a drum-shaped runner consisting of two parallel discs connected together near their rims by a series of curved blades. A cross flow turbine always has its runner shaft horizontal (unlike Pelton and Turgo turbines which can have either horizontal or vertical shaft orientation).

Unlike most water turbines, which have axial or radial flows, in a cross flow turbine the water passes through the turbine transversely, or across the turbine blades. As with a waterwheel, water enters at the turbine's edge. After passing the runner, it leaves on the opposite side. Going through the runner twice provides additional efficiency. When the water leaves the runner, it also helps clean the runner of small debris and pollution. The cross-flow turbines generally operate at low speeds.

The turbine consists of a cylindrical water wheel or runner with a horizontal shaft, composed of numerous blades (up to 37), arranged radially and tangentially. The edges of the blades are sharpened to reduce resistance to the flow of water. A blade is made in a part-circular cross-section (pipe cutover its whole length). The ends of the blades are welded to disks to form a cage like a hamster cage and are sometimes called "squirrel cage turbines"; instead of the bars, the turbine has trough-shaped steel blades.

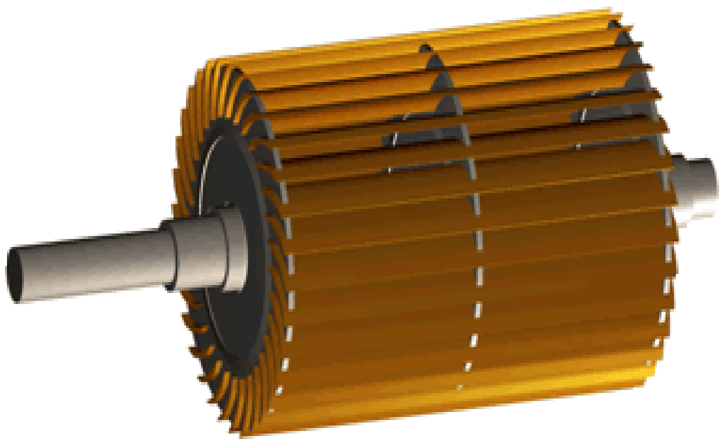

Figure 2.4: Cross Flow Turbine

Source: Joe Cole. *Crossflow Turbine Abstract.*

Reaction Turbine

Reaction Turbine are acted on by water, which changes pressure as it moves through the turbine and gives up its energy. They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow.

The more popular reaction turbines are the Francis turbine and the propeller turbine. Kaplan turbine is a unique design of the propeller turbine. Given the same head and flow conditions, reaction turbines rotate faster than impulse turbines. This high specific speed makes it possible for a reaction turbine to be coupled directly to an alternator without requiring a speed-increasing drive system. This specific feature enables simplicity (less maintenance) and cost savings in the hydro scheme. The Francis turbine is suitable for medium heads, while the propeller is more suitable for low heads.

The reaction turbines require more sophisticated fabrication than impulse turbines because they involve the use of larger and more intricately profiled blades together with carefully profiled casings. The higher costs are often offset by high efficiency and the advantages of high running speeds at low heads from relatively compact machines. Expertise and precision required during fabrication make these turbines less attractive for use in micro-hydro in developing countries. Most reaction turbines tend to have poor part-flow efficiency characteristics.

4. Francis turbine

The Francis turbine is a reaction turbine where water changes pressure as it moves through the turbine, transferring its energy. A watertight casement is needed to contain the water flow. Generally such turbines are suitable for sites such as dams where they are located between the high pressure water source and the low pressure water exit.

Figure 2.5 Francis Turbine

The inlet of a Francis turbine is spiral shaped. Guide vanes direct the water tangentially to the turbine runner. This radial flow acts on the runner's vanes, causing the runner to spin. The guide vanes (or wicket gate) are adjustable to allow efficient turbine operation for a wide range of flow conditions. As the water moves through the runner, it’s spinning radius decreases, further delivering pressure acting on the runner. This, in addition to the pressure within the water, is the basic principle on which the Francis turbine operates. While exiting the turbine, water acts on cup shaped runner buckets leaving without any turbulence or swirl and hence almost all of the kinetic or potential energy is transferred. The turbine's exit tube is shaped to help decelerate the water flow and recover the pressure.